**Abstract**

Studies that aim to characterize oxygen uptake kinetics in efforts above maximal oxygen consumption intensity are scarce. Our aim was to analyze the oxygen kinetics in a maximal 200-m front crawl, all measurements being conducted in swimming pool conditions. 10 high-level male swimmers performed a maximal 200-m bout and oxygen uptake was directly measured through breath-by-breath gas analysis. Mean ($\pm$ SD) peak oxygen uptake was 68.58 ($\pm$ 5.79) ml.kg$^{-1}$.min$^{-1}$, evidencing a fast component phase. As expected, peak oxygen uptake presented a direct relationship with mean swimming speed of the first 50-m lap and with the 200-m effort, and was also correlated with the amplitude of the fast component ($r=0.75$, $r=0.72$, $r=0.73$, $p<0.05$, respectively). The observed mean amplitude value was higher than those observed in the literature for other exercise intensity domains. However, the time for its onset, as well as the duration for attaining the steady state, was shorter, as the peak oxygen uptake was not correlated with these 2 components. Moreover, as previously described for swimming at high intensities, the slow component phenomenon was not observed. Aerobic metabolic pathway accounted for 78.6%, confirming the high aerobic contribution in middle distance swimming events.

**Introduction**

Conventionally, the oxygen uptake ($\dot{V}O_2$) kinetic response to exercise has been studied in the moderate, heavy and severe intensity domains [20], its nature and magnitude also being dependent on changes within each exercise intensity domain [15]. In moderate exercise, i.e., at intensities below the anaerobic threshold, the transition from rest to constant load exercise is characterized by an increase in $\dot{V}O_2$ as a 3-phase response [32]: following an early delay-like phase at exercise onset, lasting approximately 15–20 s (phase I), $\dot{V}O_2$ increases monoexponentially with a time constant of 30–45 s (phase II), to achieve a steady state within 3 min (phase III). In the heavy intensity domain, at exercise intensities higher than the anaerobic threshold, after a first fast rise of the $\dot{V}O_2$ kinetics, it does not achieve an early steady state but continues to rise – $\dot{V}O_2$ slow component phenomenon – until delayed steady state is achieved, exhaustion ensues, or exercise ends [4,31]. In severe exercise, in which the exercise intensity is specifically above the anaerobic threshold, and neither $\dot{V}O_2$ nor blood lactate levels can be stabilized [31], $\dot{V}O_2$ continues to increase until the point of exhaustion [20]. In this domain, $\dot{V}O_2$ slow component is much more developed than that during heavy exercise, its magnitude being dependent on the duration and type of exercise [46].

More recently, a fourth exercise intensity domain – extreme exercise – has been proposed for power outputs that lead to exhaustion before maximal oxygen uptake ($\dot{V}O_{2\text{max}}$) is attained [23]. According to Burnley and Jones [9], in this intensity domain, $\dot{V}O_2$ kinetics is characterized by the development of an evident fast component, the slow component phenomenon is not observed. In fact, extreme exercise is so intense that there is not enough time to reach $\dot{V}O_{2\text{max}}$ or for a slow component to appear. Complementarily, due to the short duration of exercise before the appearance of exhaustion, blood lactate at the end of the effort may not reach such high values as those recorded at the end of severe intensity exercise. The characteristics of $\dot{V}O_2$ kinetics in moderate and heavy exercise intensities are well documented in the literature, namely in treadmill running and cycle ergometer exercise. However, evaluations carried out in the severe and extreme exercise domains are almost non-existent. Specifically in swimming, $\dot{V}O_{2\text{max}}$ is considered to be
Table 1  Individual and mean (± SD) values for the swimmers’ main physical and performance characteristics.

<table>
<thead>
<tr>
<th>Swimmer</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Body mass (kg)</th>
<th>Fat mass (%)</th>
<th>Lean body mass (kg)</th>
<th>200-m personal best (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>23.9</td>
<td>180.5</td>
<td>74.5</td>
<td>11.0</td>
<td>60.8</td>
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</tr>
<tr>
<td>#2</td>
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<td>184.0</td>
<td>80.9</td>
<td>11.9</td>
<td>59.9</td>
<td>110.2</td>
</tr>
<tr>
<td>#3</td>
<td>20.6</td>
<td>178.5</td>
<td>67.9</td>
<td>11.9</td>
<td>60.2</td>
<td>109.3</td>
</tr>
<tr>
<td>#4</td>
<td>23.8</td>
<td>191.5</td>
<td>81.2</td>
<td>12.1</td>
<td>58.8</td>
<td>107.4</td>
</tr>
<tr>
<td>#5</td>
<td>22.8</td>
<td>195.5</td>
<td>84.6</td>
<td>11.3</td>
<td>59.2</td>
<td>110.9</td>
</tr>
<tr>
<td>#6</td>
<td>21.9</td>
<td>180.0</td>
<td>70.6</td>
<td>8.8</td>
<td>62.7</td>
<td>106.4</td>
</tr>
<tr>
<td>#7</td>
<td>20.9</td>
<td>182.0</td>
<td>69.4</td>
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<td>61.5</td>
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<td>81.4</td>
<td>7.2</td>
<td>63.0</td>
<td>111.1</td>
</tr>
<tr>
<td>#10</td>
<td>20.1</td>
<td>186.0</td>
<td>81.2</td>
<td>7.3</td>
<td>64.9</td>
<td>110.8</td>
</tr>
<tr>
<td>mean (± SD)</td>
<td>21.6 (± 2.4)</td>
<td>185.2 (± 6.8)</td>
<td>76.4 (± 6.1)</td>
<td>10.1 (± 1.8)</td>
<td>62.3 (± 3.9)</td>
<td>109.3 (± 2.1)</td>
</tr>
</tbody>
</table>

Fig. 1  Example of an oxygen consumption to time curve, identifying the time of the onset of the fast component (TD), the time constant of the fast component (τ) and the amplitude of the fast component (A).

a standard of maximal aerobic power, being one of the primary areas of interest in training and performance diagnosis in swimming [14, 34, 40]. Indeed, since Liljestrand and Stenstrom, high values of VO2max have been commonly associated with excellence in competitive swimming, and, to the best of our knowledge, only Rodriguez et al. [38] and Rodriguez et al. [37] studied VO2 kinetics in real swimming pool conditions, not in simulated conditions (i.e., in swimming-flume), for the 100-m and 400-m front crawl events in a pilot study. Knowing that studies that aim to characterize the specific VO2 kinetics in extreme intensity exercises are scarce, the purpose of this study was to characterize the VO2 kinetics during a maximal 200-m front crawl effort, all gas measurements were directly obtained in habitual training and competition swimming pool conditions.

Material and Methods

Subjects

10 front crawl elite male swimmers volunteered to participate in this study. The subjects provided informed written consent before data collection, which was performed in accordance with the ethical standards proposed by Harriss and Atkinson [22]. The inclusion criterion was a personal best time less than 115 s in the 200-m front crawl long course event. Individual and mean (± SD) values for subjects’ main physical and performance characteristics are described in Table 1. Body mass, fat mass and lean body mass were assessed through the bioelectric impedance analysis method (Tanita TBF 305, Tokyo, Japan). All swimmers were involved in more than 8 training units per week. The tests were carried out in a recovery microcycle at the end of the second macrocycle of the season.

Data collection

The test sessions took place in a 25-m indoor swimming pool with a water temperature of 27.5 °C. In-water starts and open turns, without underwater gliding, were used. After a standard competition warm-up, all subjects rested outside the water while the equipment was set up and calibrated for the experiments. Each subject performed a 200-m front crawl effort at maximal speed, receiving encouragement to swim his best effort. The mean swimming speed values corresponding to the 200-m (200 speed), and each 50-m lap (50 speed) were calculated by the ratio between exercise distances and corresponding times. VO2 kinetics was directly measured using a telemetric portable gas analyzer (K4 b2, Cosmed, Italy) that was suspended over the water (at a 2-m height) in a steel cable, following the swimmer along the pool, and minimizing disturbances of the normal swimming movements. This equipment was connected to the swimmer by a low hydrodynamic resistance respiratory snorkel and valve system [24]. Expired gas concentrations were measured breath-by-breath and averaged every 0.2 Hz [42]. Using this sampling interval, the highest VO2 value during the 200-m swim was considered as the peak oxygen uptake (VO2peak). The VO2 value just before the beginning of the exercise was also measured (VO2). After the end of the 200-m maximal bout, expired air was continuously measured until the swimmers VO2 values were achieved. Capillary blood samples for lactate concentrations ([La−]) were also assessed (Lactate Pro analyzer, Arkay, Inc) from the earlobe at the end of the warm-up ([La−]b), immediately after the test, and during the recovery period (1, 3, 5 and 7 min), until maximal values were reached ([La−]max). Δ[La−] was considered as the difference between the [La−]max and [La−]b, which was used to estimate the partial contribution of both aerobic and anaerobic pathways (as described in the Metabolic pathways assessment section).

VO2 kinetic parameters

The VO2 kinetics was fitted by the following model, in which the exponential term started after a certain time delay (TD in the equation):
component (ml.kg\(^{-1}\).min\(^{-1}\)). TD is the time for the onset of the fast component (s) and \(\tau\) stands for the time constant of the fast component, i.e., the time to reach 63\% of the plateau of this phase (during which physiological adaptations adjust to meet the increased metabolic demand). A nonlinear least squares method was implemented in MatLab environment for the adjustment of this function to VO\(_{2}\) data. The non-existence of a slow component was also confirmed by the fixed intervals method, consisting of the difference between the last VO\(_{2}\) measurement of the exercise and the value measured in the final 5s of the 200-m event [17, 25]. An example of the VO\(_{2}\) uptake kinetics during the maximum 200-m front crawl protocol is shown in Fig. 1.

**Metabolic pathways assessment**

The partial contribution of the aerobic (Aer\%) and anaerobic (Anaer\%) energy systems during the maximal 200-m effort were assessed as described in equation 2 (adapted from [14, 26]):

\[
\text{Anaer\%} = \left(\frac{O_2\text{Eq}[\text{La}]^-}{[\text{VO}_2 - \text{VO}_2\text{b}] (t - \tau/60)} + \left(\frac{O_2\text{Eq}[\text{La}]^-}{[\text{La}]^-}\right)\right) \times 100
\]

where \(O_2\text{Eq}[\text{La}]^-\) is obtained by the product of the \(\Delta[\text{La}^-]\) by the 2.7 mlO\(_2\).kg\(^{-1}\).min\(^{-1}\) proportionality constant, VO\(_2\) and VO\(_{2b}\) are considered as the average between 3 consecutive values just after and before the 200-m maximal bout (respectively), \(t\) is time (min), \(\tau\) is the time constant (s). The Aer\% was obtained by subtracting 100 by the Anaer\% value.

**Statistical analysis**

Mean (±SD) computations for descriptive analysis were obtained for all variables and for the entire group of subjects (all data where checked for distribution normality with the Shapiro-Wilk test). Simple linear regression and Pearson’s correlation coefficient were also used. All statistical procedures were conducted with SPSS 10.05 and the significance level was set at 5%.

**Results**

200-m self-imposed maximal pace test

Table 2 shows the 200\(_{\text{speed}}\), 50\(_{\text{speed}}\), VO\(_{2\text{peak}}\), VO\(_{2b}\), [La\(^{-}\)]\(_{\text{max}}\), A, TD and \(\tau\) values reached during the 200-m front crawl maximal effort. VO\(_{2}\) kinetics response in the 200-m front crawl maximal effort started with a sudden and exponential increase in VO\(_{2}\) close to the beginning of the effort, as shown by the TD and \(\tau\) mean values, respectively (Fig. 1, Table 2). The A mean value indicated that swimmers were able to attain high values of oxygen consumption, maintaining these during the 200-m all-out event. Afterwards, a fast transition period was observed to be needed to attain a steady state (\(\tau\)), followed by a steady state period, in which a VO\(_{2}\) slow component phenomenon was not evident.

### Table 2: Individual and mean (±SD) values for 200\(_{\text{speed}}\), 50\(_{\text{speed}}\), VO\(_{2\text{peak}}\) (absolute and relative), VO\(_{2b}\), [La\(^{-}\)]\(_{\text{max}}\), A, TD and \(\tau\) in the 200-m maximal effort.

<table>
<thead>
<tr>
<th>Swimmer</th>
<th>200(_{\text{speed}}) (m s(^{-1}))</th>
<th>50(_{\text{speed}}) (m s(^{-1}))</th>
<th>VO(_{2\text{peak}}) (l min(^{-1}))</th>
<th>VO(_{2\text{peak}}) (ml.kg(^{-1}).min(^{-1}))</th>
<th>VO(_{2b}) (ml.kg(^{-1}).min(^{-1}))</th>
<th>[La(^{-})](_{\text{max}}) (mmol.l(^{-1}))</th>
<th>A (ml kg(^{-1}) min(^{-1}))</th>
<th>TD (s)</th>
<th>(\tau) (s)</th>
</tr>
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<tbody>
<tr>
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<td>1.47</td>
<td>5.24</td>
<td>69.88</td>
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<td>66.67</td>
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<td>11.6</td>
<td>44.50</td>
<td>4.99</td>
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<td>45.40</td>
<td>4.99</td>
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<tr>
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<td>45.63</td>
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<td>7.05</td>
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<tr>
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<td>1.63</td>
<td>5.60</td>
<td>69.03</td>
<td>10.04</td>
<td>13.0</td>
<td>50.18</td>
<td>4.99</td>
<td>13.41</td>
</tr>
</tbody>
</table>

### Metabolic pathway percentage

The mean estimated contributions of aerobic and anaerobic metabolisms during the 200-m effort were 78.6\% (±2.9) and 21.3\% (±2.9), respectively.

### Relationships between the studied variables

Complementarily to the above referred data, direct relationships between 200\(_{\text{speed}}\) and VO\(_{2\text{peak}}\) (\(r = 0.69, p = 0.03\)), [La\(^{-}\)]\(_{\text{max}}\) (\(r = 0.73, p = 0.02\)) and A (\(r = 0.64, p = 0.04\)) were observed (Fig. 2A). The same trend is reported for 50\(_{\text{speed}}\) and VO\(_{2\text{peak}}\) (\(r = 0.75, p = 0.01\)), [La\(^{-}\)]\(_{\text{max}}\) (\(r = 0.72, p = 0.02\)) and A (\(r = 0.70, p = 0.02\)) (Fig. 2B). Another direct relationship was obtained between VO\(_{2\text{peak}}\) and A (\(r = 0.73, p = 0.01\)) (Fig. 2C). No significant correlations were found between VO\(_{2\text{peak}}\) (expressed in absolute and relative values) and other VO\(_{2}\) kinetic parameters, particularly TD (\(r = 0.07\)), both for \(p > 0.05\). The absence of significant relationships was also observed between the swimming performance and the VO\(_{2}\) kinetic parameters: (i) 200\(_{\text{speed}}\) with TD (\(r = 0.14\)) and \(\tau\) (\(r = 0.01\)), both for \(p > 0.05\), and (ii) 50\(_{\text{speed}}\) with TD (\(r = -0.25\)) and \(\tau\) (\(r = -0.09\)), both for \(p > 0.05\).

### Discussion

The aim of this study was to describe and analyze the specific VO\(_{2}\) kinetics of extreme intensity swimming effort: the 200-m maximal front crawl effort. After the pilot study of Rodriguez et al. [38], this is, to the best of our knowledge, the first attempt to monitor the VO\(_{2}\) uptake kinetics during this specific middle-distance swimming event. This is novel and extremely important since the testing was conducted in normal swimming pool conditions, overlapping the standard laboratory conditions that may not perfectly reflect the real-world performances [8]. VO\(_{2}\) kinetics was assessed using up-to-date procedures for col-
lecting and measuring breath-by-breath expired gas, disposing the data in real time. The modified snorkel and valve system, specific for breath-by-breath gas analysis, has already been considered suitable for measurements during swimming [24]. For the \( \text{VO}_2 \) kinetics analysis, a sampling frequency of 0.2 Hz was used, since the breath-by-breath gas acquisition could induce a significant variability of the acquired \( \text{VO}_2 \) values, overestimating them. In accordance with several studies [2,8,28,42], the 0.2 Hz sampling frequency has a good temporal resolution, being more appropriate than other lower sampling frequencies for this kind of study. Additionally, accepting that the concept of \( \text{VO}_{2\text{max}} \) is more related with constant load exercise testing [9], \( \text{VO}_{2\text{peak}} \) was used as a measure of aerobic power.

**\( \text{VO}_{2\text{peak}} \)**

In the swimming related literature, few attempts have been conducted in order to assess \( \text{VO}_2 \) kinetics parameters using direct oxymetry protocols in real swimming pool conditions. Moreover, studies that aimed to characterize the specific \( \text{VO}_2 \) kinetics in extreme intensity exercises are almost non-existent. When the 200-m was performed at maximal effort, swimmers began at a very high swimming intensity. Thus, from the very beginning of the exercise the need for oxygen in muscles triggered an instantaneous and sudden increase in the \( \text{VO}_2 \) uptake. Indeed, the \( \text{VO}_2 \) values were very high just after the first 50-m lap, and most of the subjects were able to maintain these high \( \text{VO}_2 \) values for almost all of the 200-m effort. Considering the total sample, \( \text{VO}_{2\text{peak}} \) ranged from 60.19 to 81.79 ml min\(^{-1}\)kg\(^{-1}\), which is in accordance with previously obtained data in national and elite male competitive swimmers [18,34,36,40,47]. However, among these studies, only Reis et al. [34] implemented a swimming effort at intensities similar to our protocol, i.e., in the extreme intensity domain. In the specialized literature, other studies were also conducted in real swimming pool conditions, but involved swimmers with lower performance levels [17,27] and used different test distances [37,38], which seems to explain the reported lower \( \text{VO}_{2\text{max}} \) mean values compared to the present study. This fact seems to be explained by the higher performance level and training background of the present tested swimmers, and by the specificity of the testing protocol.

**\( \text{VO}_2 \) kinetics related parameters**

In moderate constant speed exercise bouts, the cardiodynamic phase of the \( \text{VO}_2 \) kinetics, representing the early fast increase in \( \text{VO}_2 \), is usually completed within the first 15–25 s of exercise [46], while the fast component increases monoexponentially with a \( \tau \approx 30–45 \) s [30]. However, in the extreme intensity exercise domain, the \( \text{VO}_2 \) kinetics assumes an exponential rise that is cut off at \( \text{VO}_{2\text{max}} \) before the \( \text{VO}_2 \) slow component has time to develop, a \( \text{VO}_2 \) steady state not occurring [9,45]. In fact, in the present study, the \( \text{VO}_2 \) slow component was not observed, although it was previously described in swimming for slower intensities [13,17,37,38]. During the analyzed effort, only 2 distinct components were observed: the cardiodynamic phase, which was not taken into consideration (due to its insignificant value in terms of amplitude), and the fast component, which started a few seconds later than the effort onset. During the fast component, the increase in amplitude is described to be linearly related to the increase in exercise intensity [5,7,11,12,32,39]. In fact, the mean amplitude value observed is higher than the one previously described for elite swimmers [1,33]. High values of this parameter are directly related to best performances in the 400-m front crawl event [19], which seems to corroborate that the aerobic contribution to the total 200-m front crawl energy supply is also very important. The fact that subjects with higher percentage of type I muscle fibres have a lower amplitude value in the fast component phase [5], indicates that future swimming related studies should consider analyzing the relationship between phenotypic
expression of muscle fibres and the amplitude value of the fast component of \( \dot{V}_O_2 \) kinetics.

Several treadmill running and cycling ergometer studies showed that \( \tau \) remains remarkably constant as exercise intensity increases, despite increasing lactic acidosis [3, 5–7, 11, 32, 39, 46]. However, the observed \( \tau \) mean value is lower than those reported previously for higher effort distances [1, 33, 38], which means that a faster attainment of the \( \dot{V}_O_2 \) steady state occurred in the 200-m effort. This seems to be physiologically useful since the existence of a shorter lag in the unbalance of \( \dot{V}_O_2 \) demand and supply implies a reduced requirement for anaerobic energy provision during the transition from rest to exercise [9], which helps to conserve intramuscular glycogen reserves [30]. It has previously been described that aerobic elite trained athletes have remarkably faster fast component \( \dot{V}_O_2 \) kinetics that enables them to minimize the magnitude of the oxygen deficit, which could reduce the perturbation of homeostasis, typical of a transition from a lower to a higher metabolic rate [3]. Additionally, Alves et al. [1] proposed that shorter \( \tau \) mean value is related to higher aerobic fitness and performance level in aerobic swimming events, which reflects an enhanced potential for oxidative metabolism. Nevertheless, in the present study a significant relationship between \( \dot{V}_O_2 \)peak and \( \tau \) was not found, corroborating the findings of Rodríguez et al. [37], Rodríguez et al. [38] and Fernandes et al. [19], suggesting that \( \tau \) is not a good predictor of performance in this middle-distance swim (namely due to its high variability among swimmers). Complementarily, Pringle et al. [32] previously observed a negative correlation between the \( \tau \) of the fast component and the percentage of type I fibres for heavy exercise \((r = -0.68, p \leq 0.01)\), meaning that subjects with a low percentage of type I fibres tended to have longer \( \tau \) than subjects with a high percentage of type I fibres. From this perspective, it might be hypothesized that, due to genetic predisposition and/or to the type of training, the swimmers of our sample may have a high Type I phenotypic expression of muscle fibres that lead to shorter \( \tau \) values. According to Barstow [3], a simple monoexponential description of \( \dot{V}_O_2 \) kinetics shows that the \( \tau \) magnitude rises as the exercise intensity increases, especially when accompanied by sustained elevations in blood lactate (i.e., above the lactate threshold). In fact, Rodríguez et al. [38] and Rodríguez et al. [37] used monoexponential descriptions of \( \dot{V}_O_2 \) kinetics and showed higher mean \( \tau \) values for the 100- and 400-m swimming efforts.

According to the literature, significant differences in the TD values associated with the fast component are observed only between heavy and severe exercise [32]. In fact, in the present study, the fast component of the \( \dot{V}_O_2 \) kinetics started almost at the beginning of the effort, contrarily to the results reported before [1, 33]. It should be highlighted that the present study was conducted in the extreme intensity exercise domain, and the referred studies were conducted in heavy intensity, the selection of very high swimming velocities at the beginning of the exercise not being evident.

### Relationship between \( \dot{V}_O_2 \)peak and swimming performance

The observed relationship between \( \dot{V}_O_2 \)peak and \( \dot{\tau}_{0peak} \) (and \( \dot{\tau}_{0speed} \)) is in accordance with studies conducted at different swimming distances: Rodríguez et al. [38] \((r = 0.787\) and \(r = 0.752,\) for the 100-m and 400-m, respectively), Rodríguez et al. [37] \((r = 0.84\) and \(r = 0.78,\) for the 100-m and 400-m, respectively) and Fernandes et al. [19] \((r = 0.93,\) for the 400-m). In fact, although \( \dot{V}_O_2 \)peak is a major influence in the 400-m distance, the results of the present study show that \( \dot{V}_O_2 \) is also a good predictor in the 200-m distance, confirming the relevance of the aerobic contribution to energy demands in other events than the long-distance ones [19, 35, 36, 38, 40]. However, the determination coefficient value obtained between \( \dot{V}_O_2 \)peak and \( \dot{\tau}_{0speed} \) indicates that other factors (like anaerobic capacity) might help to explain the performance in this specific distance. The observed direct relationship between amplitude and \( \dot{\tau}_{0speed} \) (and \( \dot{\tau}_{0speed} \)), as well as between this kinetic parameter and \( \dot{V}_O_2 \)peak, emphasizes the importance of this kinetic parameter as a good predictor of the 200-m event performance.

In the study’s 200-m front crawl a 78.6% of aerobic energy contribution was observed, which reflects the significant role of the aerobic metabolism pathway even in high intensity exercise [21]. Although different approaches have been used to assess anaerobic energy pathway (transformation of the net blood lactate concentration into \( O_2 \) equivalents or through the accumulated oxygen deficit), the aerobic contribution is slightly higher than those proposed by Ogita [29] and Capelli et al. [10] for 2–3 min bouts and 182.9 m distances (65 and 61.5%, respectively), by Troup [43, 44] (71.7, 60 and 61%, respectively) and Zamparo et al. [47] (71.7%, both for the 200-m swim. However, it is lower than the results presented by Silva et al. [40] (85%) and Reis et al. [34] (87%), both for the 200-m swim. Complementarily, Rodríguez & Mader [36], through computer simulation, proposed aerobic contributions for the 400-m (83.2%) and 100-m (54.1%) events. Nonetheless, the method by which energy release is determined can have a significant influence on the calculated relative contribution of the energy systems during periods of maximal exercise [21], which can explain this variability. The competitive level of the subjects tested may also help to explain the differences obtained.

The protocol used allowed to characterize \( \dot{V}_O_2 \) kinetics in a 200-m maximal effort, carried out in normal swimming pool conditions. The \( \dot{V}_O_2 \)peak mean value is in accordance with the literature for elite male competitive swimmers. Also, direct relationships between swimming speed and \( \dot{V}_O_2 \)peak amplitude and \([La]_{max}\) were found, confirming that developed aerobic capacity plays a central role among the energy-yielding mechanisms in middle distance swimming. However, the amplitude, \( \tau \) and TD mean values were different from those observed in the literature (presenting high inter-subject variability), which seems to be explained by the intensity domain in which the event was carried out. It was also confirmed that \( \dot{V}_O_2 \) slow component was not observed in swimming extreme efforts (as previously reported for laboratory running and cycling), in opposition to what occurs at slower swimming paces.

However, since swimmers performed 200-m at race pace, different pacing strategies were adopted, which may explain distinct \( \dot{V}_O_2 \) kinetics. In addition, the fact that no starting from block and the use of open turns, without underwater gliding, could have limited the swimmers’ performance, and consequently influenced \( \dot{V}_O_2 \) kinetics.

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